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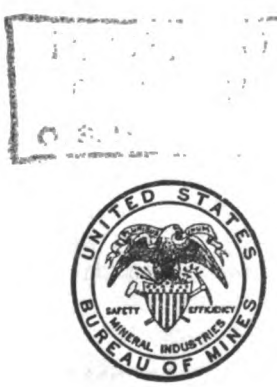
SAMPLING AND TESTING OF A GOLD-SCHEELITE PLACER DEPOSIT IN THE MOJAVE DESERT, KERN AND SAN BERNARDINO COUNTIES, CALIF.



BY

H. W. C. PROMMEL

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SAMPLING AND TESTING OF A GOLD-SCHEELITE PLACER DEPOSIT IN THE MOJAVE DESERT, KERN AND SAN BERNARDINO COUNTIES, CALIF.[1]

By H. W. C. Prommel[2]

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[2] Consulting geologist and mining engineer, Denver, Colo., and one of the consulting engineers, U. S. Bureau of Mines.

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INTRODUCTION

The increase in the price of gold in 1933 was the cause of starting many activities in gold prospecting and mining; it led to investigations of many of the so-called desert placers in the Southwest, which heretofore had not been deemed of commercial importance. Among these, attention was called to some of the gravel beds in the vicinity of the Randsburg-Atolia mining districts of Kern and San Bernardino Counties, Calif., in which gold and scheelite, (calcium tungstate, CaWO4) were said to be present. Following a partial sampling and testing of the gravel, large-scale operations were begun in 1935. During the same year more detailed sampling and testing of the gravel beds were done by the author. During 147 days, 1,239 test holes 28 inches in diameter were drilled; their total depth amounted to 16,705 feet. These test holes furnished 2,495 samples of an average volume of 1.0583 cubic yards bank run each; all of the material was run through a sample mill constructed on the property. Original and rather unusual sampling and testing methods had to be used; milling and mining methods for large-scale operations also offered difficulties. The primary purpose of this drilling and sampling campaign was to determine, over a large area, the amounts of gold and scheelite recovered by placer methods such as were already in use on the property. This paper describes sampling and testing methods employed by the author during the 1935 drilling campaign.

LOCATION

The gold and scheelite placer deposit is in the Atolia tungsten mining district about one-half mile west of the small mining town of Atolia and about 5 miles south of Randsburg in the Randsburg gold-mining district. The deposit lies near the foot of the Rand Hills in the Mojave desert. The territory is served by hard-surfaced roads from the north and south; Los Angeles is 150 miles to the southwest. A branch of the Southern Pacific Railroad passes within 5 miles of Randsburg.

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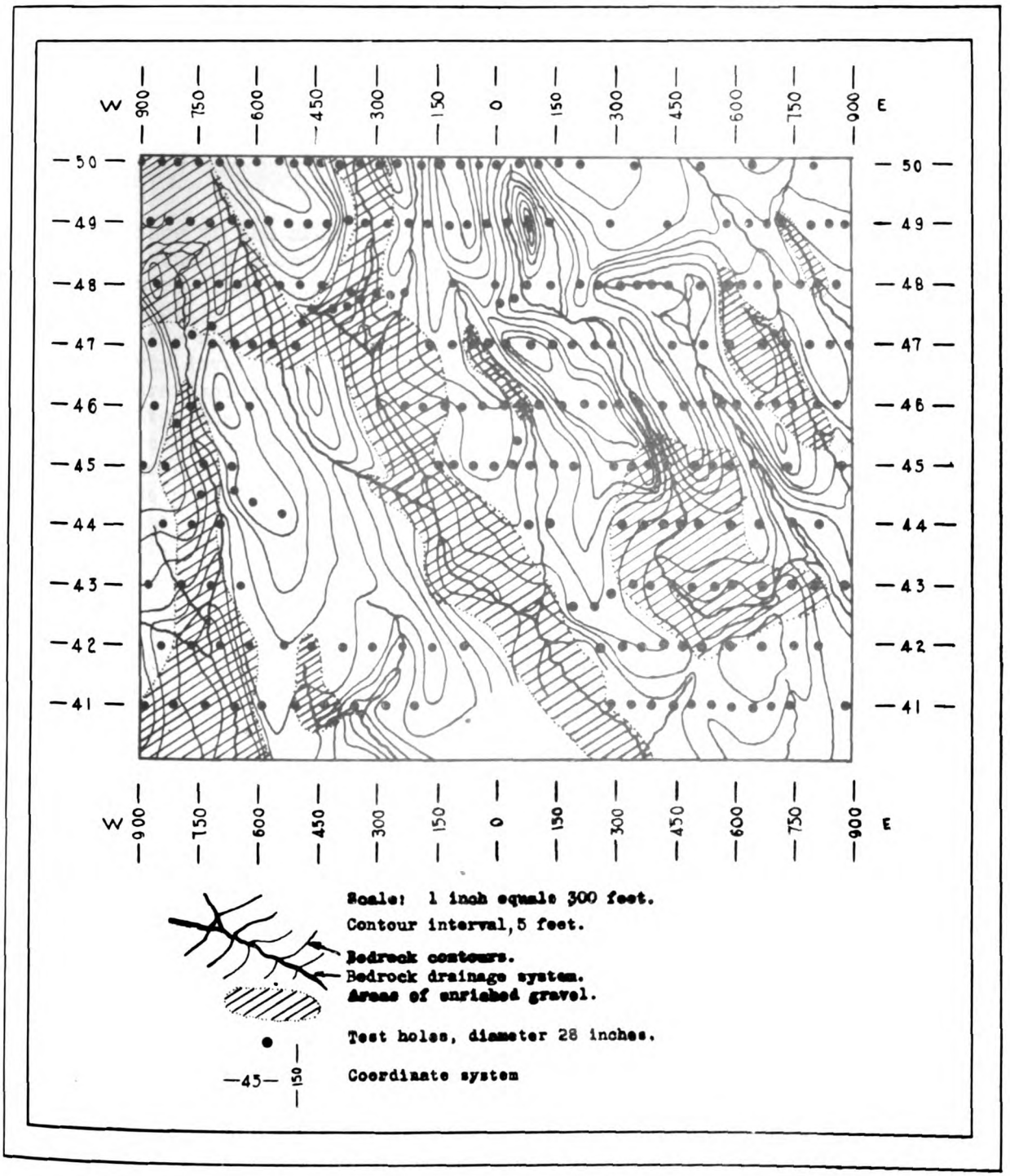

Figure 1.– Part of Atolia Rand placer, San Bernardino County, Calif.

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HISTORY

Gold mining has been carried on in the Randsburg district since 1895. The production of tungsten began in the Atolia district during the World War, and large quantities of scheelite were extracted from both lode and placer deposits. The district is credited with a tungsten production valued at more than 9,000,000 dollars. Some gold-lode prospecting has been carried on to the south and southwest of Atolia, but it was not until 1932 that the prospecting of surface gravels for both gold and scheelite was undertaken seriously.

PHYSIOGRAPHY

The surface of the area discussed forms a featureless, gently undulating plain with a general slope of the surface to the southeast of 150 feet to the mile. Altitudes range from 3,200 to 3,600 feet. The drainage of the area is from the Rand Hills in a southerly to southeasterly direction toward Cuddeback Lake, one of the many dry lakes of the Mojave desert; surface-drainage channels are very poorly developed. Except during run-offs of sudden and violent storms, none of the drainage channels carry water; there is no constant underflow. For very short intervals after storms, water stands about a foot deep in Cuddeback Lake, but it soon seeps downward to the permanent water level at about 100 feet below the lake-bed surface. The water is slightly salty and unfit for domestic purposes. The principal vegetation is scattered patches of greasewood. The climate is that of the Mojave desert, extremely hot in summer and relatively cold in winter. Strong windstorms are common at all times.

GEOLOGY

The desert placer deposits south of Randsburg are of recent age; concentration of gold and scheelite was induced intermittently by freshets and cloudbursts rather than by constant stream action. The many gold-bearing quartz stringers of the Randsburg mining district, less than 5 miles north, suggest a source from which the gold in the gravel wash originated. The gravels also show scheelite enrichment for about a mile downstream from an east-northeasterly trending shear zone traversing the metamorphic, quartz monzonite, and granite country rock. Along this zone several rather ill-defined and irregular veins of scheelite ore have been developed. Both upgrade and downgrade from this enriched zone the scheelite content of the gravel diminishes rapidly. Gold in the gravels increases upgrade toward the Randsburg district from the scheelite vein zone. The thickness of the gravel beds, which consist principally (90 percent or more) of fine, angular material up to 2 inches in size, with occasional boulders along the bedrock drainage channels, varies from 15 feet at the north to over 65 feet at the south. Where the thickness exceeds 30 feet, the gold-bearing layers are irregularly distributed through the gravel section. In some places the upper 15 to 20 feet of gravel can be mined profitably, while at other places comparatively narrow streaks of pay gravel have been found below 60 feet of nearly barren overburden.

The data obtained from the many test holes drilled during 1935 made it possible to construct a bedrock contour map of a large part of thearea. A part of this map is shown as figure 1. The map also shows the test holes, the

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drainage channels developed in the bedrock, and some of the enriched areas of placer gravel. Although in a few instances the subsurface channels conform to present surface-drainage systems, subsurface drainage and topography is more pronounced and more irregular than present surface drainage and topography. For instance, over the bedrock channel extending from coordinate 50-0 to coordinate 42-900E (fig. 1), the present surface is practically flat. In the northern part of the area the main surface-drainage channel follows the principal bedrock channel in a general way. Farther south, where the gravel wash thickens, it loses its identity with respect to subsurface drainage.

The general slope of the bedrock surface underlying the gravel wash is 160 feet to the mile to the southeast. In the southern part of the area where the overlying gravel section is thicker, the bedrock slope increases to approximately 350 feet per mile. Although several deep channels exist there seems to be only one main bedrock channel along which the principal concentration of valuable minerals has taken place. At flood times this channel apparently could not carry the entire run-off and flooded adjacent minor channels. Concentrations of gold and scheelite occurred in irregular patches in the minor channels, which were controlled at all times, however, by the course of the main channel as well as by high places or hillocks in the bedrock. In this respect, attention is called to the enriched gravel area between coordinate 42-45, 300-900E (fig. 1). Preliminary test drilling seemed to indicate a continuous pay channel paralleling the main channel. Intensive drilling, however, covering this suggested channel from north to south showed that the gold and scheelite completely disappeared in its northern part but were reconcentrated within a basin in the vicinity of a sharp bend in the drainage pattern caused by higher and more resistant bedrock to the south and west. The gravel in this basin is extremely coarse from the surface down to bedrock and presented many difficulties in test drilling. The character of this gravel suggests with little doubt that it had been deposited from farther up the channel during extremely heavy cloudbursts and that it represented considerably enriched, rewashed, and reconcentrated material.

Some local enrichment of shallow gravel in sparsely distributed patches, uncontrolled by bedrock configurations, is probably coming from mineral-bearing quartz stringers that traverse the bedrock within the gravel area itself. Along the main bedrock channel, gold and scheelite are not evenly distributed, which gives rise to rich as well as poor spots along its winding course. The general direction of this channel is south-southeast, but innumerable bends and potholes, too small to be shown on the map, occur along its course. Figure 1 represents a part of the area downgrade from the scheelite-vein zone.

The angular shape of the material making up the gravel beds and the absence of well-rounded waterworn boulders strongly suggest a nearby source. Occasional fragments of quartz showing many fine stringers of native gold also suggest a nearby source, so near, in fact, that much of the gold of the gravel beds has not been liberated as yet from its matrix and is not recoverable by ordinary placer milling methods. Fire assays of samples obtainedfrom the sides of some of the test holes confirm this opinion, so that in many places the gold content of the gravel is twice that recoverable by concentration without additional grinding. The exact relationship between placer gold and contained gold has not yet been accurately determined; a method of economical extraction of both placer and contained gold remains to be worked out.

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Sampling of some of the test holes over depths coinciding with those of placer samples already obtained and run would give the percentage of gold not recovered by placer-milling methods. Microscopic examination of the material would furnish data on the character and distribution of the retained gold as well as on the matrix material. This may determine whether or not grinding of the material to a finer mesh will liberate most of the gold, so that much of it can be recovered by concentration and amalgamation, or whether cyanidation or some other process will be necessary. The evolution of a successful method depends on careful research work and cost estimates.

The drainage system of the Randsburg-Atolia district radiates from it in various directions and other gold-bearing gravel deposits are present in the region. Other deposits probably exist under similar conditions in other desert regions of the west, close to the source from which the gravel or wash originated. These desert deposits offer a field for research work which in the end may provide methods and processes by which gold thus distributed in nature can be reclained economically.

WATER

Prior to 1934, the absence of water for placer purposes had made large-scale operations impossible. A small amount of water was piped to the Atolia district from a deep well on Red Mountain and sold for domestic purposes at 1 cent per gallon. However, arrangements had been made with the Atolia Mining Co. to acquire the water system that furnished salty water from Cuddeback Lake for milling purposes at its Atolia mine. A 4-inch pipe line from Cuddeback Lake, 7 miles long, and a Ponona pump were installed to lift the water from its underground level to a concrete-lined storage reservoir at the edge of the lake bed. A triplex pump raises the water from this point to the half-way storage basin, from whence another pump delivers it through the line to the Atolia mine and to the placer deposit. A part of the line was later increased in size to 6 inches. The water is raised 750 feet; about 250 gallons per minute is furnished for the large-scale placer operations and added to the closed water circuit in use.

SURVEY METHODS AND MAPS

No maps, apart from those showing mining claims of the district, were available. As the drilling of a large number of test holes was anticipated, a plane-table survey of the property was made. The Kern-San Bernardino County boundary line served as a primary north-south base line; a second base line was run at right angles to it across the property, and a coordinate system was established. All measurements were taken with a 300-foot steel tape. Locations of prominent objects, such as the Atolia No. 1 headframe and others, were determined by triangulation from the base lines. Orientation in any part of the field was by backsight and checksight on triangulation points; buildings, roads, dumps, pits, and other surface improvements were tied in by stadia.

East-west coordinate lines, 150 feet apart, were numbered from 0 to 95 northward; north-south lines, also 150 feet apart, were numbered from a

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north-south center line to the east and to the west, with the number of feet they were distant from the center line. (See fig. 1.) Tracings from the plane-table sheets served as progress maps upon which all data were plotted as accumulated. During the survey work a topographic map of a part of the property also was made, and locations for test holes were staked out. Building lath, sawed in two, pointed on one end and planed on one side, was used for stake material. In order to prevent fading of numbers by the sun, stakes were driven so that the numbered side faced north. Short pieces of discarded pipe, painted white, with survey numbers stenciled on them, were used as permanent markers in the field. Complete records of all survey work were kept, and the work was added to constantly as test hole drilling progressed.

Flags and targets were used in backsighting as well as in marking lines of test holes to be drilled. In order to hasten the setting and removal of marker flags, so-called "flag bases" were made. These consisted of a short piece of 1-1/2-inch pipe about 6 to 8 inches long, which was welded parallel to a 5/8-inch iron rod of the same length; this, in turn, was welded parallel to the blunt end of a pointed iron rod about 2 feet long; the whole, when driven into the ground, formed a supporting collar, into which the lower end of the flag pole was loosely placed. These "flag bases" were easily driven and loosened, and flag poles were not subjected to hammering and breakage. The method was adopted from similar target bases already in use. These older bases were equipped with threaded pipe collars; the end of the target pole was permanently fitted into a piece of threaded pipe, which, in turn, screwed into the collar of the target base. The survey crew consisted of the author and two assistants from the sampling crew.

DRILLING METHODS

The ground was tested by drilling with two portable, rotary, drilling rigs using auger-type buckets. This kind of drill was developed on the coast for digging cesspools and is locally termed a "California cesspool digger."

The area to be tested was large and sinking of test pits by hand was too slow and expensive. Ordinarily, a Keystone percussion drill using 6-inch-diameter casing and 7-1/2-inch drive shoe is used for drilling test holes on placer deposits. This method will, theoretically, deliver 0.0114 cubic yards of material for every foot depth of drill hole. Dry gravel and the absence of boulders here made it possible to use the cesspool digger with good results. With these drills, test holes averaging 28 inches in diameter could be put down. This method furnished 13.9 times the amount of material for a sample that could be obtained by Keystone drilling. The larger the sample, the closer its gold and scheelite content approaches the actual values in the placer ground. The average of 2,495 samples thus taken, representing an average depth of 6.7 feet per sample, was 1.0583 cubic yards by bank measure. The samples were run through the sample mill.

The rotary drills were mounted on 3-ton trucks (figs. 2A and 2C) and were driven by the truck engine through power take-offs from the drive shafts. The drill consisted of a 30-foot wooden mast that could be lowered for long

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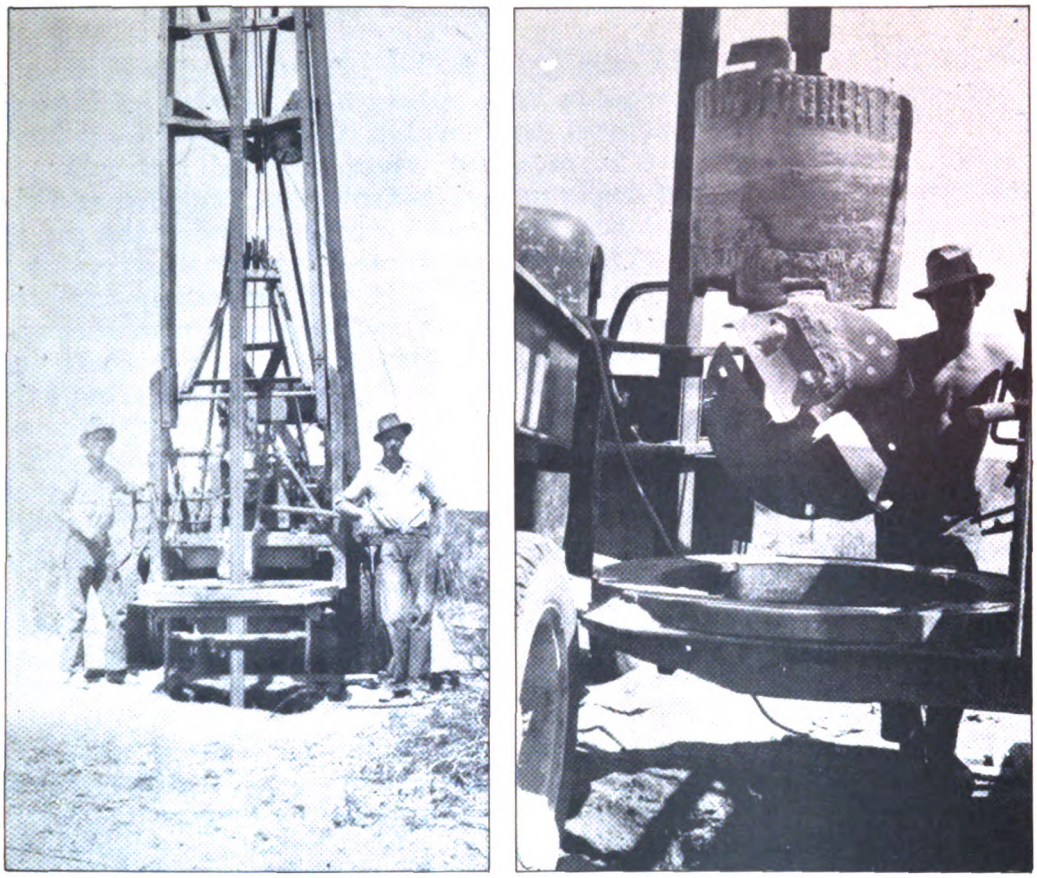
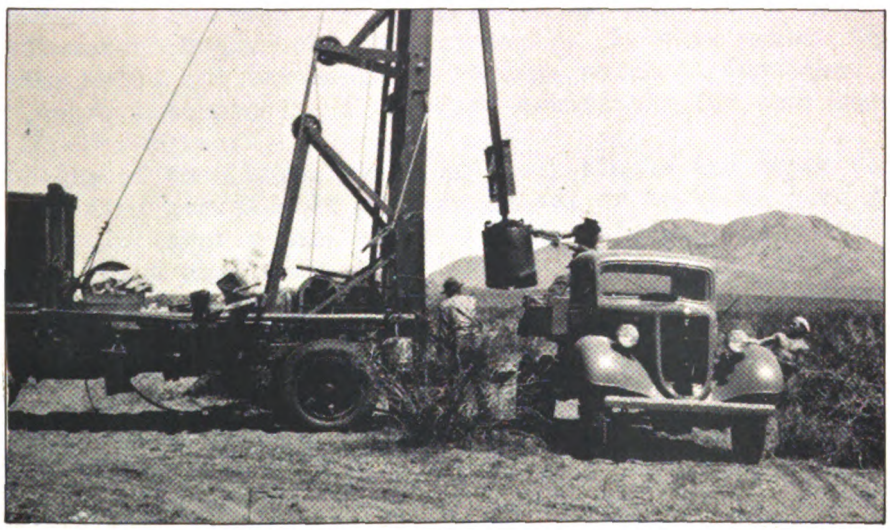


A B



C

Figure 2.— California cesspool-digger rotary drill: *A*, Rear view, wrench and kelly bar in position inside of covered ring gear, with auger bucket in test hole; *B*, close-up of auger bucket, bottom open for discharge of sample. Note attachment and shape of two cutting blades at edge of large holes in bucket bottom; *C*, pulling auger bucket over dump truck for unloading part of sample from test hole.

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hauls, a horizontally mounted, 36-inch ring gear (figs. 2A and 2B) at the rear end of the truck, rotated by a pinion gear attached to an auxiliary shaft, and a small, double-drum hoist for raising and lowering the mast and the drilling equipment. The drilling equipment consisted of several lengths of drill stem, a square kelly bar, and a 24-inch-diameter auger bucket. This bucket was 2 feet high and had a conical, hinged bottom with two large openings, to the edges of which two cutting blades were bolted (fig. 2B). Upon rotation of the bucket, the blades would scrape the material into it. At first, rubber flaps were used over the openings to help retain the material in the bucket. These were discarded later, as it was found that by adding a small amount of water while drilling, dry material could be moistened sufficiently to pack. This also prevented the sides of the hole from caving. A lever arrangement held the hinged bottom of the bucket in place while drilling was going on, and allowed it to be opened so that the contents of the bucket could be emptied into a dump truck. The square kelly stem that was attached to the bucket by a box joint and single bolt, fitted through a wrench, engaged by protrusions in the ring gear, thus giving the stem and bucket their rotary motion inside of the ring gear. In drilling deep holes, several lengths of drill stem were required. They were fitted together by box joints and single bolts so that drill stems could be removed and added quickly and simply.

The drilled material stood up well, and no casing or lining was required in any of the 1,239 holes put down. The holes were of fairly constant diameter, somewhat larger than the diameter of the auger bucket; they were large enough for a man to be lowered into them and, by means of a calibrated sliding staff, for measuring the diameter of the hole for every foot of depth and to clean the bottom of the hole thoroughly by hand. If the hole was irregular in places, several measurements were taken at the same depth in order to obtain the average diameter of the hole at that depth. In this manner the average diameter of the hole, and the bank-run yardage which it furnished for each sample depth, were determined and recorded separately for each sample.

The drilling of test holes was relatively simple and rapid as long as the drill worked in fine gravel. If coarser gravel or boulders were encountered it became necessary to lower a man into the hole to loosen the coarser rocks and to collect them in an auxiliary small bucket. This was a very slow procedure in very cramped quarters. In order to speed the work a 1-1/2-inch fishtail bit was constructed from an automobile axle in such a way that it could be fitted to the drill stem instead of the bucket and drill a central blast hole about 2 feet deep. A small amount of dynamite usually was sufficient to loosen the material; the larger rocks were then picked out and work proceeded with the auger bucket.

But even this method was not always successful, especially when cemented gravel was encountered. To speed drilling in such instances, a pounding bit 24 inches in diameter and weighing 3,000 pounds was obtained from Los Angeles. A carriage for this bit, properly balanced, was constructed from discarded angle iron, I-beams, and an automobile axle. Two reinforced tire rims welded together were fitted over each wheel of the carriage to provide better traction. The bit resting on this carriage was towed to the drill by a dump truck, up-ended, attached to one of the drill lines and lowered into the

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hole. The rotary drills were not equipped with walking beams; the bit was lifted a short distance and allowed to drop quickly, in this manner crushing and fracturing the rocks so that they could be removed by the auger bucket.

Of the drilling equipment, the side of the auger bucket and the scraping blades were subjected to the greatest wear and tear. The bucket was reinforced occasionally by electric-welding layers of cast iron (in the shape of vertical strips) onto its sides. The scraping blades were made of plow steel and could be resharpened. On the average, two sets of blades per drill per 8-hour shift were used.

The spacing of holes (rather arbitrary at first) was speedily reduced from 275 feet, on rows 400 to 450 feet apart, to 50 feet, on east-west rows 150 feet apart (in a few instances 100 feet apart); the rows coincided with the coordinate system. (See fig. 1.) Test holes were staggered on alternate rows. The longest row measured 4,800 feet and contained 97 holes.

Test-hole drilling was started in June 1935 and continued uninterruptedly until November 9 of that year. At the beginning, one drill worked one 8-hour shift per day; this was stepped up to two 8-hour shifts during July and August. From August 28 two drills working two 8-hour shifts each were employed. The drills were kept working close to each other, so that three 1-1/2-ton steel-body dump trucks could service the drills and haul the samples to the sample mill.

No excavated material was left to mark the position of the test holes; this constituted a menace to safe travel over the ground. In order to avoid accidents and liability therefor, wooden fences made of waste material were first built around each hole. This kept one carpenter busy, and the waste material was soon exhausted. Old pipe, boiler tubing, and galvanized wire then were resorted to for fence material. Discarded boiler tubing was purchased and cut into 4-foot lengths in Los Angeles. A roll of galvanized wire was carried on each drill and fence posts were distributed over the area to be drilled by the truck drivers, who, with one of the assistants at each drill, were responsible for fencing each test hole as soon as it was finished. A galvanized-iron tag (made from waste material), into which the serial number of the test hole as well as its coordinate location numbers were stenciled, was wired to each fence.

In order to synchronize speed of drilling, truck capacity, and sample-mill capacity, and to obtain a fair-sized sample per yard depth, one level truckload was decided upon as the average sample. This, on the average, furnished a little more than 1/2 cubic yard of material per yard depth and gave one sample for every 6 to 7 feet of test-hole depth; bottom samples usually represented less depth.

The personnel at each of the two drills consisted of the driller, one assistant, and one roustabout, the latter being required to assist in pulling the auger bucket over the dump truck to discharge it. He also leveled the load in the truck and assisted in building fences around finished holes. Two truck drivers took care of three dump trucks. The work accomplished, as well as averages, are set forth in table 1. All yardage figures represent bank-run measure; average diameter of holes was 28 inches.

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TABLE 1. - Summary of test-hole drilling, June to November 1935

Month	Days	No. of holes	No. of feet drilled	No. of samples	No. of cubic yards in samples	Aver. no. holes per day	Aver. no. feet per day
June--	16	114.0	1,071.6	166	162.4	7.1	67.0
July--	31	233.5	2,320.0	379	379.1	7.5	74.8
Aug.--	31	350.5	2,907.7	492	471.9	11.3	93.8
Sept.-	30	281.0	4,428.7	631	700.2	9.4	147.6
Oct.--	31	197.0	4,830.6	664	743.4	6.4	155.8
Nov.--	8	63.0	1,146.8	163	183.5	7.9	143.4
Total	147	1,239.0	16,705.4	2,495	2,640.5	8.4	113.6

Month	Days	Aver. no. samples per day	Aver. no. cubic yards in sample per day	Aver. cu. yds. per sample	Aver. depth holes	Aver. depth holes per sample	Aver. depth holes per cu.yd.	Deepest hole, feet
June--	16	10.4	10.2	.9786	9.4	6.5	6.59	32
July--	31	12.2	12.2	1.0000	9.9	6.1	6.12	32
Aug.--	31	15.9	15.2	.9591	8.3	5.9	6.16	57
Sept.-	30	21.0	23.3	1.1097	15.8	7.0	6.32	67
Oct.--	31	21.4	24.0	1.1196	24.5	7.3	6.50	59
Nov.--	8	20.4	22.9	1.1257	18.2	7.0	6.25	66
Total	147	17.0	18.0	1.0583	13.3	6.7	6.32	67

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Drilling during June, July, and August was on a somewhat irregular time basis. Drilling data and averages for the months of September and October, during which two drills worked uninterruptedly two 8-hour shifts each per day, provide more significant figures; they are as follows:

Total number of drilling days	61
Number of holes drilled	478
Total feet drilled	9,259
Number of samples obtained	1,295
Cubic yards gravel in samples	1,444

	Averages per day, 2 drills, 2 eight-hour shifts each	Average per drill per eight-hour shift
Number of holes	7.8	1.95
Number of samples	21.2	5.3
Cubic yards gravel	23.7	5.9
Feet drilled	151.8	37.95

Average cubic yards per sample	1.1151
Average depth of test hole, feet	19.4
Average depth per sample, feet	7.1
Average depth per cubic yard	6.41

THE SAMPLE MILL

By March 1935 a pilot mill, assay office, and large stationary concentration plant had been constructed. As the pilot mill was not in use, it could be utilized as a sample mill. This necessitated considerable reconstruction, however, for the following items had to be given consideration:

1. New machinery and design had to be built into the existing framework of the pilot mill.

2. The same general flow sheet - recovery of gold and scheelite by concentration - that had already been installed in the large plant was to be followed in the sample mill; nevertheless, flexibility in the flow sheet was desirable to allow quick changes in methods and additions to the mill circuit for experimental purposes.

3. The sample mill was to be designed so that it could be converted quickly into a pilot mill of 100 cubic yards per day capacity.

4. Samples ranging in volume from 1 cubic foot to several cubic yards were to be treated; the sampling mill was to have a maximum capacity of 25 cubic yards bank-run gravel per day.

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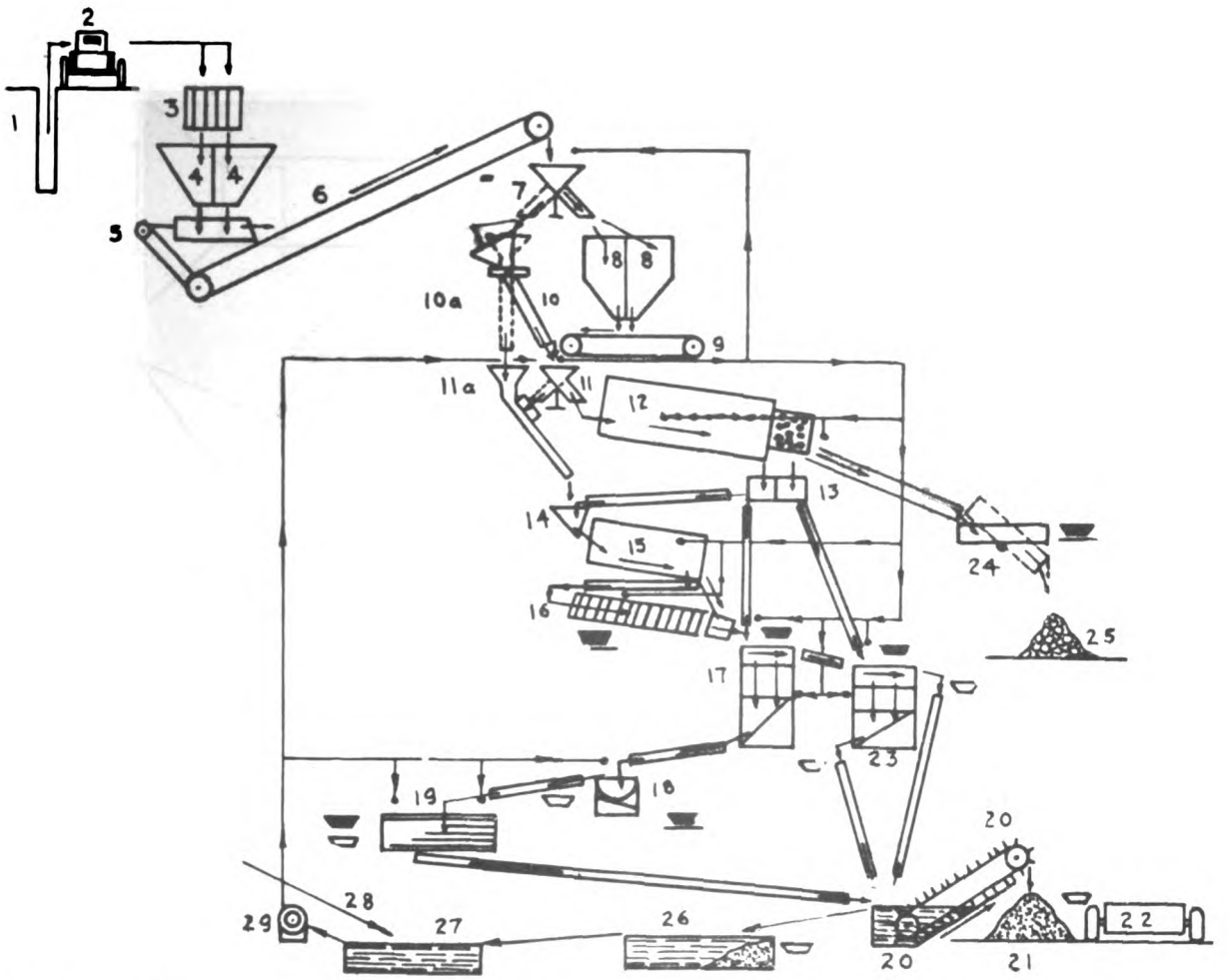

1 Test hole, 28" diam.
Aver.depth per sample, 6.7 ft.
Aver.cu.yds.per sample, 1.0583
2 Dump truck
3 Grizzly, 5" spacing
4 Storage bins
5 Variable-stroke mechanical feeder driven from conveyor pulley shaft
6 Belt conveyor, var.-speed motor
7 Multiple-feeder funnel
8 Measuring and storage bins
9 Variable-speed feeder belt
10 Hinged feed funnel and pipe (10a)
11 Multiple-feeder funnel
11a Direct feed line to GB hopper
12 Scrubber and trommel screen, 5/8" and 2" diam.holes
13 Distributor box; flow of fines adjustable to GB hopper or direct to Bendelari jig
14 GB hopper
15 GB trommel screen
16 GB shaking rubber riffle
17 Bendelari jig, 26", single cell
18 Centrifugal separator.
19 Overstrom concentrating table
20 Dewaterer
21 Dewatered tailings, minus 2"
22 Le Tourneau scraper
23 Bull jig
24 Tilting sorting table, plus 2"
25 Tailings, plus 2"
26 Slimes-settling basin
27 Clear-water tank
28 Fresh-water inlet. 29 Centr. pump

Connecting launders and direction of flow
Water circuit — Water outlets
Gold and scheelite concentrates collected for each sample
Scheelite concentrates collected every 24 hours
Places in flow sheet were daily tailings samples were taken

Figure 3.— Sample-mill flow sheet, Atolia Rand placers, San Bernardino County, Calif.

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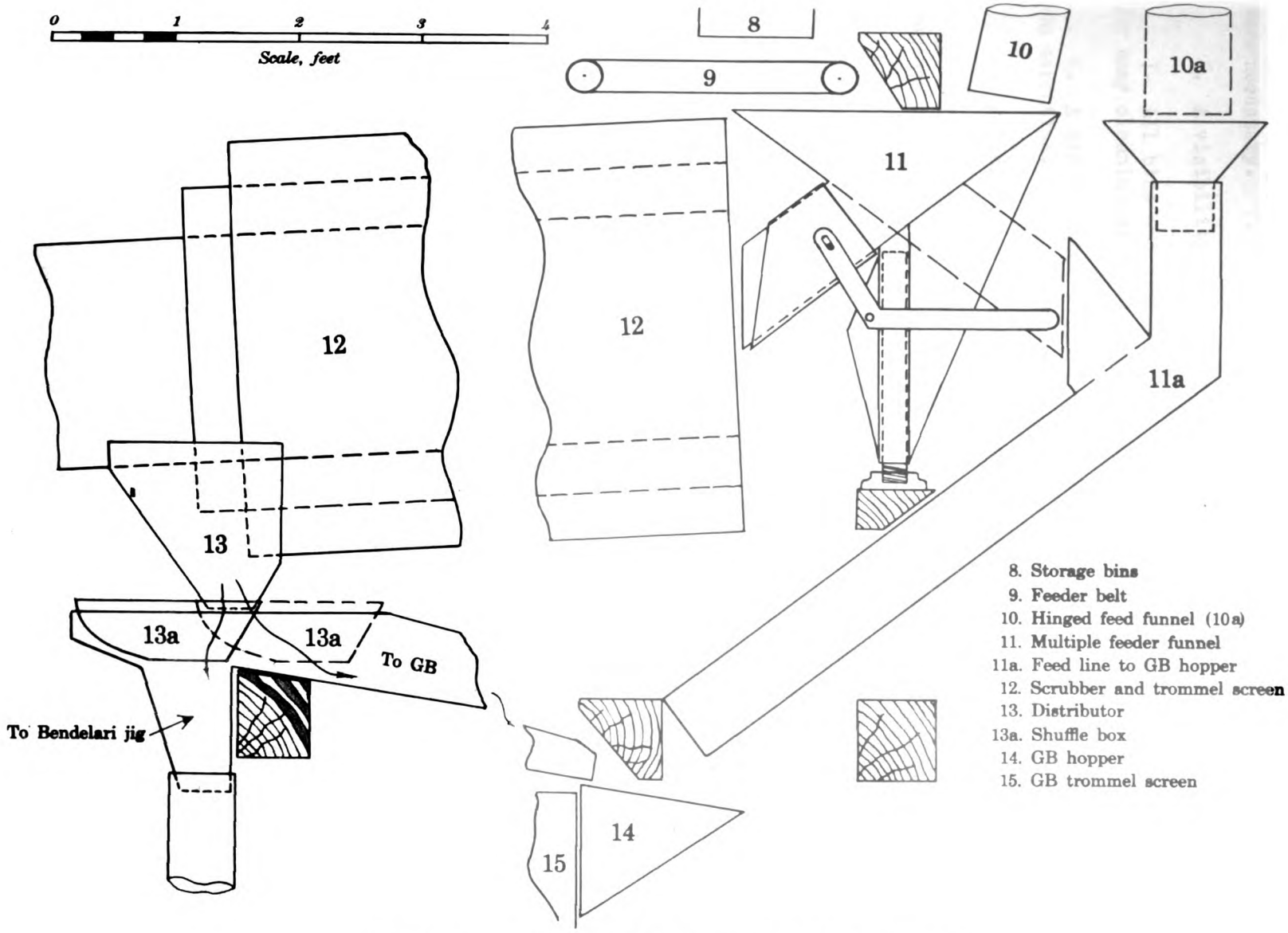

Figure 4.—Details of sample-mill installations nos. 8 to 15 of figure 1.

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5. Clean-ups of all gold and some scheelite concentrate for each sample were necessary.

6. A visibility of flow at all places in the circuit was desired.

7. All bins and launders had to be tight, without traps, and designed for easy cleaning after the run of each sample.

8. A closed water circuit requiring the minimum addition of fresh water was essential.

9. All gravity flow of the material was desired.

10. The mill was to serve later on for sampling as well as for clean-up purposes of scheelite concentrated from the large plant.

Of the material already in the mill, a trommel screen, one bull jig, one 12-inch centrifugal gold separator designed by H. H. Morse, one Overstrom concentrating table, and a tailings dewaterer were retained, although their position was changed. A 26-inch, one-cell, Bendelari jig and a GB sampling machine with shaking rubber riffle were added. All new bins, connecting launders, and feed funnels were designed on the property. The larger pieces of sheet iron for bin linings, etc., were cut to size in Los Angeles, where some of the feed funnels were also manufactured. All bin linings and launders were arc welded to insure tight joints. Launders and hoppers were constructed sectionally and installed so that they could be removed easily for repairs.

A bucket elevator that had served the pilot mill was replaced by a 24-inch belt conveyor leading from the storage bins to the top of the mill. The arrangement of the machinery and the flow of the material through the mill is shown on figure 3. Three dump trucks and four bins provided storage for seven 1-1/4-cubic yard bank-run samples.

From the test hole the auger bucket was emptied directly into the iron dump box of the truck, which unloaded at the receiving bins (No. 4) over grizzlies with 5-inch spacing (No. 3). The oversize was sorted for large chunks of scheelite and piled on the ground; it was removed when necessary by a LeTourneau tractor. The undersize was fed from the iron-lined bins into a mechanical adjustable feeder (No. 5) driven from the lower pulley shaft of the conveyor (No. 6). The conveyor was driven by a variable-speed electric motor. The speed of delivery of a 1- to 1-1/4-cubic-yard sample to the multiple feeder funnel (No. 7) could be varied from 8 minutes to 45 minutes or more, depending on whether the sample was to be stored and its swell from bank run measured in the calibrated storage bins (No. 8), or whether a direct feed of the sample was desired.

If a direct feed to the upper trommel screen (No. 12) or to the hopper (No. 14) of the GB trommel screen (No. 15) was desired, the feeder funnel (No. 7) was turned to empty into the hinged feeder funnel (10, 10a). By a simple rotation of the feeder funnel on its vertical support (see also No. 11 fig. 4) it would empty into either one of the two storage bins (No. 8).

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An adjustable-speed feeder belt (No. 9) driven by sprocket wheel and chain from one of the trommel roller-wheel shafts delivered the material through another feeder funnel (No. 11) either to the large trommel screen or to the GB hopper. Water was added to the dry feed at feeder funnel 11 or 11a. Water was also available at the upper funnel (No. 7) but was seldom introduced at that point.

The direct-feed circuit from conveyor or bins to the GB hopper served for small samples of fine composition. The material from the test holes was very dry and required considerable scrubbing and washing; most samples, therefore, were first run through the large scrubber and trommel screen (No. 12), in which the oversize (plus 5/8-inch) was thoroughly washed by sprays. The plus 2-inch material was discharged onto a sorting table (No. 24), where occasional chunks (locally known as "spuds") of scheelite were recovered before the table was tilted to discharge the oversize waste. The plus 5/8-inch minus 2-inch material discharged from the hopper (No. 13) onto the bull jig (No. 23) for concentration of occasional pieces of scheelite.

The fines (minus 5/8-inch) passed from the hopper (No. 13) to the GB hopper (No. 14) or directly to the Bendelari jig (No. 17) cutting out the GB trommel and rubber riffle (No. 16) entirely. This was advisable at times and was also done to divert the flow of water from the GB machine when the concentrate was removed from the riffle at the end of a sample run. The quick change was effected by moving a so-called bottomless "shuttle box", illustrated in greater detail (No. 13a) in figure 4; its position could be changed quickly by operating a simple lever in front of the GB machine. The circuit most used was from hopper 13 to GB hopper 14. Figure 4 shows some of the details of installations No. 8 to No. 14 as well as some of the supporting timbers the positions of which could not be altered.

In the trommel screen of the GB machine the minus 5/8-inch material was subjected again to a thorough scrubbing, the minus 1/8-inch material passing over the shaking rubber riffle (No. 16) to the Bendelari jig (No. 17), while the plus 1/8-inch material went directly to the Bendelari jig. Provision was made at this point to desline the minus 1/8-inch material before it reached the Bendelari jig and pass the slimes through a small feeder funnel over stationary riffles, blankets, or amalgam plates, thence to the slimes-settling basin (No. 26). However, results from slimes tailings samples showed that this installation was not necessary.

In the Bendelari jig, coarse scheelite concentrated on the jig bed; tails passed onward to the bull jig, while the fine black sand, gold, and scheelite concentrates passed through the Bendelari screen into the hutch and thence into the centrifugal separator (No. 18). The overflow as well as the hutch product from the bull jig emptied into the dewaterer (No. 20).

In order to give the minus 5/8-inch material an additional scrubbing and washing before it reached the Bendelari jig, the GB machine was installed ahead of it. This caused overfeeding of the GB rubber riffle and some loss of fine gold at this point, which, however, was caught later by the centrifugal separator. The overflow from the separator went to the Overstrom concentrating table (No. 19), where the fine scheelite concentrates were recovered, and

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the overflow was passed to the dewaterer (No. 20).

The dewatered tailings were removed from the discharge pile (No. 25) by a LeTourneau scraper. The slimes passed from the dewaterer to slimes settling basins (No. 26). The flow of water and slimes through the settling basins was opposite to the direction of prevailing winds; this arrangement materially aided in settling the water. Water from the settling basins entered the clear-water reservoir (No. 27), where fresh water (No. 28) was added when necessary. A centrifugal pump (No. 29) lifted the clear water to the sample mill, where it was distributed as shown on figure 3.

All motor-control switches were centrally located on the GB floor of the sample mill. A two-way bell and signal system controlled the flow of electric power to the motors in various parts of the mill.

The mill personnel consisted of a shift boss and two assistants; one man was stationed at the hopper bins (No. 4), one at the GB machine (No. 15), and the other at the Overstrom table (No. 13). After a sample had been run from one of the bins (No. 4) and the bin as well as the automatic feeder was brushed out, an assistant followed the feed to the top of the mill, stopped the conveyor by bell signal, cleaned out feeder funnels 7 and 11, washed the trommel screen, stopped it by bell signal, and returned to his post at the hopper bins. The man stationed at the GB machine then collected the concentrates from the rubber riffle and signaled to the third man on the ground floor to recover concentrates from the centrifugal separator, while he quickly sorted the plus 2-inch material on the sorting table and tilted it to discharge the waste. A similar clean-up procedure was followed when feeding was done from the storage bins (No. 8). By proper cooperation and signalling, the shut-down time in any part of the mill between individual sample runs was kept below one minute.

The concentrates from the rubber riffle, centrifugal separator, and sorting table containing all the gold and a proportion of the scheelite were combined for each sample. Every 24 hours the scheelite concentrates from the jigs and Overstrom table were also collected, and all concentrates were transferred to the assay office. The individual sample concentrates were panned down by hand; the scheelite was removed, dried, weighed, and recorded; the gold was collected by amalgamation, the amalgam was dissolved in dilute nitric acid, and the gold was annealed, weighed, and recorded. The composite scheelite concentrate from the jigs and Overstrom table was dried and its weight recorded against the serial numbers of the samples from which it had been obtained. The system of conversion from weight to "cents per cubic yard" figures is discussed under "System of Records".

Tailings samples were collected at regular intervals throughout a 24-hour day at the following points: (1) Bull jig tails, (2) bull jig hutch, (3) centrifugal separator tails, and (4) drag (final) tails.

Slimes and black-sand samples were also taken at regular intervals. Tailings-sample results were posted and plotted graphically every day on the bulletin board in the mill. Any undue losses in tailings, therefore, could be checked and remedied speedily.

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During June, July, and August the sample mill was operated two 8-hour shifts per day; from August 25 to November 9 it operated three 8-hour shifts daily. During a 145-1/2-days run it was shut down 1-1/2 days on account of water and power shortage as well as to replace screens on the large trommel.

SYSTEM OF RECORDS

The thought carried in mind throughout the sampling campaign was to obtain a yardage and valuation estimate as well as to systematize all records so that they formed a permanent and reliable guide to future sampling and exploitation.

A form, Plane-Table Notes (fig. 5), was used in conjunction with the plane-table maps. This form is amply subdivided for recording and checking all essential field data and calculations. The location entry for each test hole shows its survey number, serial number (rotation in which test holes were drilled), as well as its coordinate numbers. This record, consisting of 86 pages of plane-table notes, gives elevations, locations, and other survey data on some 1,800 surveyed points, inclusive of test-hole locations.

The Drillers Report (fig. 6) was made out for each day for the operations of each drill. The tabulated data were checked in the office, and the total number of holes drilled, samples obtained, drilling time, moving time, delays, actual drilling time per foot of hole, and total time per foot of hole were added; 227 such sheets were covered in the drilling campaign.

A sample tag (fig. 7) accompanied each sample from the test hole, through the mill, went to theassay office with the concentrate, and finally reached the sampling office. Besides other data, the tag showed truck and bin measurements for "swell" determinations if desired and diameter recordings for every foot depth of hole. A total of 2,545 samples from test holes and dumps were thus tagged.

The Daily Sample Mill Report (fig. 8) was made out by the mill shift bosses; columns were totaled for each 8-hour shift. Considerable data, such as grand totals of all columns, total number of cubic yards run, milligrams gold recovered, average milligrams gold per cubic yard run, percent loss in tailings, loss in tailings expressed in cents per cubic yards, and percent recovery were added in the office. The report also showed average time per sample run, per foot of hole, and per cubic yard; weights of tailings samples and milligrams of gold recovered from them were shown, as were the calculations to determine losses per cubic yard. For calculation of the daily "scheelite factor", the combined weight of scheelite recovered from the jigs and Overstrom table and the combined weight of scheelite recovered from the sorting table, GB riffles, and centrifugal separator were recorded. This factor was used in computations of "cents per cubic yard" scheelite figures for each sample. One hundred fifty-three sheets made up the sample-mill record.

The Test Hole Data record (fig. 9) gave condensed information from sample tags, drillers records, and sample-mill records, as well as cubic yards of bank run represented by each sample, conversions to "weights" and to "cents per cubic

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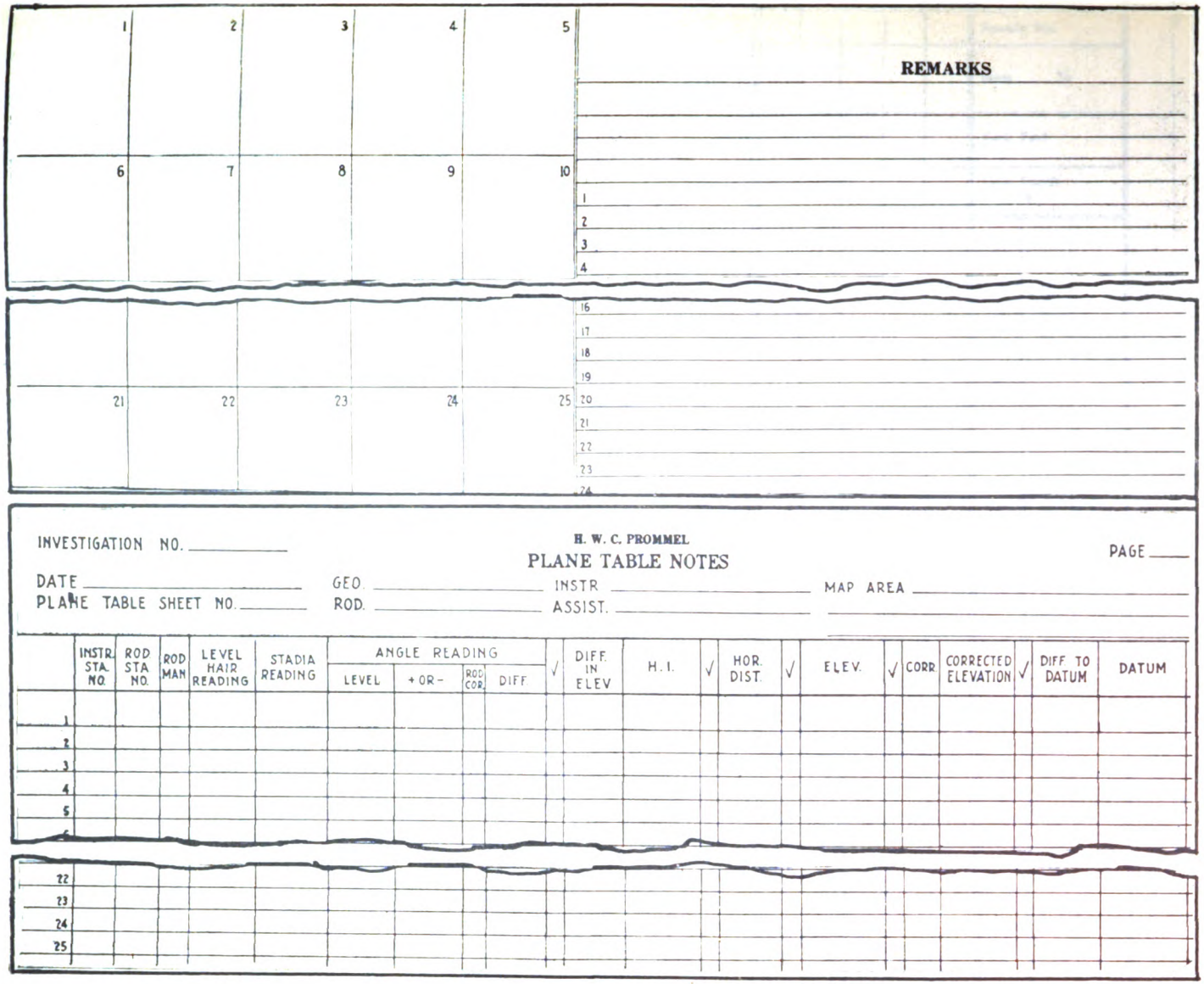

Figure 5.— Plane-table notes.

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Drillers Report

Claims_____ Driller_____

Helper_____

Date_____ Shift_____ Helper_____

Truck Driver_____

Hole No.	Sample No.	To / From	Vert. Feet	Total Depth of Hole	TIME									
					DRILLING			MOVING			DELAYS			
					Start	Fin.	Time	From	To	Time	From	To	Time	CAUSE

Figure 6.– Drillers report.

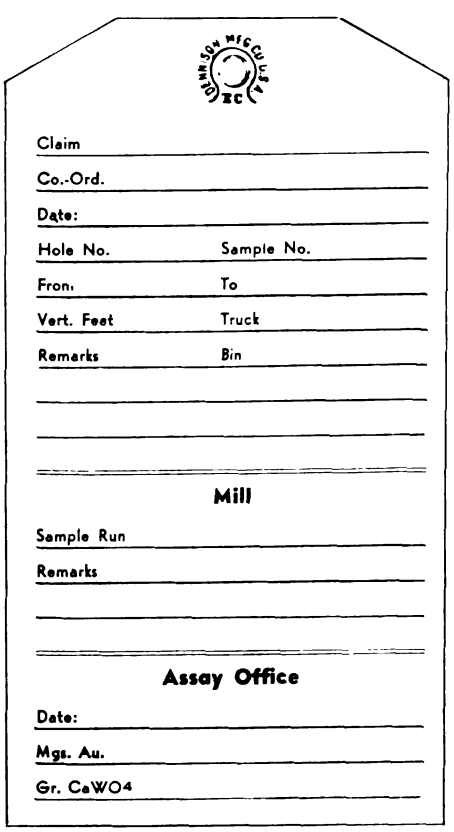

Figure 7.– Sample ticket.

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Daily Sample Mill Report

Date_____ Shift Boss_____

Shift_____ Mill Man_____

Feeder_____

Hole No.	Sample No.	From	To	Vert. Feet	FLOW RECORD									TIME						
					Bin	Direct	Trommel	G. B.	Dewat.	Bendel.	Split	Ainley	Table	SAMPLE			SHUT-DOWNS			
														Start	Fin.	Time	From	To	Time	CAUSE

Figure 8.— Daily sample-mill report.

Test Hole Data

Hole No.	Sample No.	From	To	Vert. Feet	Total Depth of Hole	HOLE Aver. Diam. Inches	CU. YDS. IN PLACE	TRUCK Inches in Truck	Cu. Yds. in Truck	% Swell in Truck	BIN Inches in Bin	Cu. Yds. in Bin	% Swell in Bin	SAMPLE Au Mg. in Sample	$CaWO_4$ Gr. in Sample	CUBIC YARD Au Mg. P. Cu. Yd.	Cents Au P. CU. YD.	$CaWO_4$ Gr. P. CU. YD.	Cents $CaWO_4$ P. CU. YD.	DATE	Remarks

Figure 9.— Test-hole data.

TEST HOLE AND BEDROCK RECORD

Hole No.	Co-ordin. No.	Survey No	Elev. collar	Depth to bedrock	Elev. bedrock	Rem.	Flag	Fence

Figure 10.— Test-hole and bed-rock data.

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yard" values for gold and scheelite for each sample and the average gold and scheelite values in "cents per cubic yard" for each test hole. It gave all data necessary for yardage and value calculations of drill-hole lines and gravel blocks between such lines. This record, made up of 124 legal-size sheets, also furnished statistical data for semi-monthly progress reports.

The Test Hole and Bedrock Record (fig. 10) was made out in the office as drilling progressed. It served as a basis for construction of a bedrock-contour map, a part of which is shown on Figure 1. This record was also used for checking on test-hole fences and location flags.

Drillers report, daily sample-mill report, and test-hole data sheets were made out in triplicate so that copies were regularly available to the general manager on the property as well as to the Los Angeles office.

Scheelite and Volume Factors

The concentrate from a separate sample contained only a proportion of the scheelite present in the sample. A quick method by which the value of all scheelite contained in the sample could be calculated in terms of cents per cubic yard of gravel was worked out as follows:

From the daily mill report and sample tags the aggregate weight of scheelite recovered for each sample from the GB riffle, centrifugal separator, and the sorting table was known; the weight of scheelite recovered each day from the jigs and Overstrom table also was known. Let us say, then, for instance, that the figures below represent scheelite recovered in the sample mill for a certain 24-hour day.

	Grams	Percent
Jigs and Overstrom table	8.0	23
Riffle, centrifugal separator, and sorting table	26.2	77
Total	34.2	100

The grams scheelite reported for each sample under the Cubic Yard heading on the Test-Hole Data sheet represent scheelite recovered by the GB riffle, the centrifugal separator and sorting table only, which for the given day amounted to 77 percent of the scheelite present in a cubic yard of bank-run gravel. As an example, suppose that for value computations for scheelite, the scheelite be taken as 40 cents per pound as recovered from the samples. The equivalent value of a gram of scheelite is 0.0882 cents. The value of all scheelite in this sample, expressed in cents per cubic yard, would therefore be:

$$\frac{\text{Grams scheelite per cubic yard (riffle + bowl + sorting table) x value 1 gram/scheelite}}{0.77}$$

In the above fraction, the value of $\frac{\text{one gram of scheelite}}{0.77}$, or $\frac{.0882}{.77}$, or .1145,

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becomes a constant or factor for the day on which 77 percent of all scheelite was recovered on the riffle, bowl, and sorting table. Such a factor was worked out daily and recorded on the sample-mill report and on the test-hole data sheet corresponding to the sample-mill sheet. By multiplying the "grams scheelite per cubic yard" figures on this latter sheet by the scheelite factor for the day, the "cents scheelite per cubic yard" figures were obtained.

For quick determination of the bank-run volume which a sample represented, a "volume-factor" table was prepared; it gave volume factors for each 1/10-inch increase in diameter of test hole from 23 inches to 37 inches. Multiplying the depth, in feet, of the sample by the volume factor opposite the average diameter of the test hole for the sample depth, gave the cubic yards of bank-run gravel contained in the sample.

Sample-mill concentrates were taken to the assay office every morning. The sample tags, with panning results, etc., recorded on them, reached the office at noon the same day; all test-hole data calculations, made on an electrically operated Monroe calculator, usually were completed within 2 hours thereafter.

BLOCK YARDAGE AND VALUE CALCULATIONS

After completion of parts of the bedrock-contour map, enriched gravel areas, as determined by test-hole locations and values, were superimposed on the bedrock-contour map and the relation between them and bedrock configuration was studied. The results often led to additional drilling as well as adjustments in the size and shape of enriched gravel areas before block-yardage and value calculations could be made.

The usual calculation methods for placer mines were followed to determine block yardages and their values in gold and scheelite. They are best summarized as follows:3/

> The area between two holes, which is ordinarily a trapezoid, is the average of their depth multiplied by the distance between them; the value of this area is the average (geometric) value of the two holes multiplied by the area; the value of the line (line or section represented by test holes) is the sum of all these products in one line, plus the sum of all these products in the second line, divided by the added areas of the two cross sections, and multiplied by distance between the lines.

Sections of test-hole lines were drawn to scale on profile paper and depths of holes and gold and scheelite values were noted on them. The different steps above outlined and all calculations connected therewith were recorded below these sections. All calculations were checked by another

3/ from Drilling for Placer Gold, Keystone Driller Co., Beaver Falls, Pa., 1908.

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Block no.	Cubic yards	Values per cu. yd. in cents			Value of block in dollars			Remarks
		Gold	Scheelite	Total	Gold	Scheelite	Total	

Figure 11.—Yardage and value data.

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person. The yardage and gold and scheelite values of 98 blocks of gravel were thus determined. The yardage was divided into three categories, as follows:

A. Positive yardage, determined by two or more rows of test holes 150 feet or less apart, with holes spaced along the rows 50 feet apart and in a few instances (early drilling) spaced 75 feet apart.

B. Probable yardage, determined by two or more rows of holes more than 150 feet apart, with holes spaced at 50-foot centers along the row.

C. Possible yardage, determined by one row of holes only.

"A" yardage estimates should closely approach the yardage and values as actually mined. "B" yardage may vary, either up or down, from that actually mined from these blocks, while "C" yardage is merely an indication of values that should be followed by additional sampling.

Final yardage and value data for the three categories were tabulated on a form (fig. 11).

With the above data all carefully collected, results intelligently interpreted, and calculations accurately made, the final results, as expressed on the form (fig. 11) should, within reasonable limits, indicate the amount of enriched yardage and the gold and scheelite recoverable by concentration methods. With close spacing of test holes and large size of samples the results checked very closely with actual exploitation figures. Discrepancies did arise, however, between sample values and actually recovered values from some small blocks of gravel. They were due to narrow enrichment channels, either missed by the test holes or encountered too often in proportion by them. As a whole, these discrepancies were compensating; still closer drilling would have to be done to check all small block yardage accurately. There was, however, an economic limit to the amount of sampling that could be done on "cents per cubic yard gravel" as compared to the amount of sampling usually done on "dollars per ton ore".

PERSONNEL

From August to November, when sampling operations were at their height, the personnel, exclusive of the author, was as follows:

Office, 1 assistant and 1 roustabout (assisting on surveys, making stakes, test-hole number-plates, etc.)	2
Drills (four 8-hour shifts per day), 4 drillers and 8 assistants	12
Haulage (two 8-hour shifts per day), 4 truck drivers	4
Sample mill (three 8-hour shifts per day) 3 shift bosses and 6 mill men	9
Assay office, 1 panner (part time) and 1 assayer (part time)	2
	29

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From March to September the office force and supervising force consisted of the author only; he was occasionally assisted by the assayer. From September to November an office and field assistant was employed.

DRILL SUPPLIES

The supplies consumed per drill per 8-hour shift were:

10 gallons gasoline, at 12 cents	$1.20
1/2 quart oil, at 35 cents	.175
Two sets blades, sharpened	1.60
Wear and tear, depreciation and insurance, approximately	1.00

ACCIDENTS

No major accidents occurred during the drilling and sampling campaign. Two men received minor head injuries while loosening and removing rocks from test holes. The total time loss on account of these accidents amounted to 16 man-hours.

COST FIGURES

Detailed cost figures covering the entire surveying, drilling and sampling campaign are not easily available to the author as other expense items had been combined with them by the accounting department.

Practically all of the drilling was done on a rental basis covering two drills, oil and gasoline, and wages of two drillers and two assistants for each drill. A total of 16,278 feet of test hole can be credited to the drilling company which received $16,044.61, or 98.6 cents per foot of hole. This does not include engineering and testing samples.

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